DØnote 4618

Conclusions of Mini-Workshop on PDF uncertainties and related topics

Volker Büscher, Jean-Francois Grivaz, Thomas Nunnemann, Markus Wobisch

(Dated: October 7, 2004)

This note summarizes guidelines for calculating cross-sections, scale uncertainties and PDF uncertainties in DØ Run II analyses. The recommendations are based on presentations and discussions at a Workshop at Fermilab on Sep 21, 2004.

I. INTRODUCTION

Physics analyses at the Tevatron frequently depend on various inputs from theory that are known with only limited accuracy. This includes calculation of cross-sections at various orders of perturbation theory as well as the determination of parton distribution functions (PDFs).

Often there is no unique choice of what calculation or prescription should be used in a given analysis. To address this issue, a workshop has been held with the aim of establishing a convention for these choices, attempting to identify those that give most accurate results while taking into account practical limitations.[1]

The following sections summarize guidelines that emerged as a consensus from presentations and discussions at this workshop.

II. COMMON GUIDELINES

A. K-Factors

As a general rule, the highest-order calculation available should be used when calculating cross-sections, and the dependence on kinematics should be taken into account if possible. For instance, the K-factor for Drell-Yan production should be applied as a function of mass. Similarly, generator-level cuts for ALPGEN productions should be taken into account in the calculation of the K-factor. This requires that the leading order MC and the leading order calculation used in the K-factor are based on the same PDF, and if possible use the same renormalisation scale μ_r and factorisation scale μ_f.

When calculating K-factors, care must be taken to make sure that the choices for PDF, strong coupling constant $\alpha_S(m_Z)$, μ_r and μ_f match between the leading and highest-order calculation as much as possible. In addition, the order of the PDFs used should match the order of the matrix-element calculations in numerator and denominator of the K-factor, respectively (with the exception of NNLO calculations, where one has to take a NLO PDF in case of CTEQ). K-factors for the most important Standard Model processes are tabulated in Ref. [2].

B. Scale Uncertainties

The calculation of cross-sections in perturbation theory implies a dependence on both the factorisation scale μ_f and the renormalisation scale μ_r due to missing higher order terms. For the central value, the relevant hard scale μ_0 of the process under study should be used for both μ_f and μ_r. For estimating the scale uncertainty, the variation in cross-section for scale choices $1/2\mu_0 < \mu_r, \mu_f < 2\mu_0$ should be quoted. While ideally μ_f and μ_r should be varied independently, it is acceptable to vary them both at the same time. The uncertainty due to the scale variation should be estimated using the same highest-order calculation that was used for calculating the K-factor.

C. PDFs

As a general rule, cross-sections and acceptances should be calculated using the most recent PDF set available (currently CTEQ6.1M). If the acceptance is evaluated using a LO parton-shower generator (e.g. Pythia, Herwig) the LO PDF should be used as central value. For the error calculation the acceptance calculated with CTEQ6.1M should be taken as nominal value, as the error PDFs are defined with respect to this nominal fit. Errors on cross-section and acceptance due to PDF uncertainties should be evaluated using the CTEQ presciption.[3] This implies the calculation of cross-section and acceptance for a set of PDFs (eigenvectors) that represent the experimental error at roughly 1σ level. The corresponding errors should be estimated from the deviation with respect to the central PDF and should be quoted as asymmetric errors. If both PDFs of a given eigenvector result in a deviation of the same sign, the larger of the two should be quoted as error (and zero for the opposite sign).

To avoid additional statistical errors due to limited MC statistics, the PDF uncertainties should be evaluated by reweighting MC events as a function of parton flavours f_1, f_2, parton momenta x_1, x_2 as well as μ_f. This procedure ignores PDF uncertainties that enter via initial state radiation, which is generated using Sudakov form factors obtained by backwards evolution of the PDF implemented in the MC. The size of this effect is process-dependent and its impact on cross-section and acceptance should be checked. This can be done by generating MC with the PDF eigenvector that dominates the error, calculating cross-section and acceptance and comparing with those obtained using the reweighted central PDF.

Similarly, if reweighting is technically impossible due to lack of parton information in DØ MC events, the impact of PDF uncertainties should be estimated by generating MC with the PDF eigenvectors and evaluating the differences in acceptances using a fast detector simulation or by applying acceptance cuts on the generator level.

Finally, it should be noted that some DØ MC has been produced with a LO-PDF and with α_S set to the value obtained in the LO-PDF fit. Since the α_S dependence cannot be factorized out, a residual dependence on the LO-PDF α_S will remain after reweighting.

D. Setting limits

Following the recommendations of the Ad-Hoc Committee on Limit-Setting, DØ limits in Run II analyses should be derived using either the Bayesian method or the LEP CLs method.[4]. If applicable, the result should be displayed as an upper limit on the signal cross-section and compared with signal cross-sections of a given model. PDF and scale uncertainties on the signal cross-section should be added in quadrature and indicated as $\pm 1\sigma$ bands around the central value.

The cross-section limit therefore depends on PDF and scale uncertainties of backgrounds that are subtracted as well as the PDF uncertainty of the acceptances. In most cases, these errors can be integrated out in the limit calculation assuming a Gaussian distribution. If there is a significant correlation with the PDF uncertainty of the signal cross-section, this dependence should instead be quantified by quoting cross-section limits for central and $\pm 1\sigma$ choices of these uncertainties.

To extract mass limits within a given model, the intersection of cross-section limit and signal cross-section should be quoted for the central value and the $\pm 1\sigma$ choices, taking into account the correlations between the cross-section limits and errors on the signal cross-section.

In addition, the expected cross-section and mass limits should be shown as a measure of sensitivity of the analysis.

Acknowledgments

We thank Joey Huston and Paul Telford for their very helpful input and their contributions to the workshop.

[1] *"Mini-Workshop on PDF uncertainties and related topics"*, FNAL Sep 21, 2004, `http://www-d0.hef.kun.nl///fullAgenda.php?ida=a041555`.

[2] T. Nunnemann, *"NNLO Cross-Sections for Drell-Yan, Z and W Production using Modern Parton Distribution Functions"*, DØ Note 4476; `http://www-clued0.fnal.gov/~nunne/cross-sections/nnlo_xsect.html`.

[3] J. Pumplin *et al.*, JHEP **0207**, 12 (2002); D. Stump *et al.*, JHEP **0310**, 046 (2003).

[4] V. Büscher, J.-F. Grivaz, J. Hobbs, A. Kharchilava, G. Landsberg, J. Linnemann, H. Prosper, S. Söldner-Rembold, *"Recommendation of the Ad-Hoc Committee on Limit-Setting Procedures to be used by DØ in Run II"*, DØ Note xxxx.